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SOME EFFECTS OF THE CONDITIONED SUPPRESSION PARADIGM ON OPERANT DISCRIMINATION PERFORMANCE[1]

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Three experiments were conducted with rats to determine the effects of electric shock on responding during an operant discrimination. In two of these experiments, a conditioned suppression procedure was superimposed upon a stimulus signalling the availability of food reinforcement (S^D). Response rates were greatly suppressed, not only in the warning signal periods which preceded each shock, but in the presence of S^D, and the stimulus signalling the unavailability of reinforcement (S^Δ) as well. A third experiment, in which a very mild shock was used without a warning signal, demonstrated an increased response rate in S^D and S^Δ, although this effect was rather unsystematic. In a similar study, Hearst (1965) found an increased rate in S^Δ independent of any change in the S^D rate. The present study failed to obtain Hearst's effect but illustrated a suppressive effect with a similar procedure.

Pavlov (1927) reported that a respondent discrimination may be disrupted by making the physical differences between reinforced and unreinforced stimuli quite small. Others, notably Cook (1939) and Masserman (1943) have investigated the effects of "stress" on instrumental behavior. The results from these studies are similar to those found by Pavlov, including the well known emotional behaviors which accompany the disruption of the discrimination usually referred to as "experimental neurosis". All of the aforementioned studies involved a conditioned conflict procedure.

Another type of procedure used to elicit emotional behavior has been developed by Estes and Skinner (1941). After several presentations of a stimulus which was terminated with an unavoidable shock, it was found that in the presence of the stimulus, ongoing operant behavior was suppressed. This procedure may be referred to as the conditioned suppression procedure. Insofar as this procedure elicits emotional behavior it is interesting to examine its effect upon an ongoing discrimination to which it is not directly related. In such an investigation, Hearst (1965) found that when the warning signal followed by shock was periodically superimposed upon a stimulus in the presence of which responding was reinforced with food (S^D), unreinforced responding in the presence of another stimulus (S^Δ), increased. This increased rate of behavior seems peculiar insofar as the conditioned suppression procedure nearly always decreases rates of responding. Hearst's finding raises the question: "When is the effect of the stimulus-shock pairings not only suppressive but facilitative as well?"

Facilitative effects of electric shock on consummatory behavior have been shown by several investigators (Amsel, 1950; Amsel and Maltzman, 1950; Ullman, 1951; Ducharme and Belanger, 1961; Sterritt, 1962, 1965; Sterritt and Shemberg, 1963; and Strongman, 1965, 1967). Such effects are usually confined to situations where the animal was shocked outside the experimental box or by using very mild shock. Strong shock presented during eating will almost totally inhibit food consumption or a response leading to food (Bolles, 1967).

The present experiment attempted to induce the effects reported by Hearst, but produced mixed results. This paper recounts and analyzes the effects of the conditioned suppression procedure on an operant discrimination.

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EXPERIMENT I

METHOD

Subjects

Four naive, male, albino rats of the Wistar strain, approximately 100 days old, were obtained from Canadian Research Animal Farms, Bradford, Ontario. The subjects were housed in individual cages and maintained on freely available water and Purina Laboratory Chow for three days. Beginning on the fourth day, subjects were food deprived until their weight was approximately 80% of their third-day weight. The subjects were weighed before each session, after which they received enough food to maintain their 80% weight. Water continued to be freely available in both the home cages and experimental chambers.

Apparatus

Two similar operant conditioning chambers, one a modified Gerbrands "Demonstration Unit", and the other of the experimenter's construction, were used. The chambers were housed in a Coca-Cola cooler and freezer chest which served as sound attenuators. Each chamber was equipped with a Gerbrands Rat Lever and Model D Pellet Dispenser which delivered Noyes Standard Formula Food Pellets (45 mg). Water was continuously available from a spout at the end of the chamber opposite the food dispenser. Constant current shock (S^-) was delivered *via* the grid floor and response lever from Applegate Model 250 stimulators in conjunction with Hoffman and Fleshler (1962) scramblers. Sound stimuli were supplied by a Foringer Model 1291 Masking Noise Generator and a Foringer Model 1293 Click Generator. Tape programmers, cumulative recorders, print-out counters, timers, and conventional relay scheduling and recording equipment were housed in an adjacent room. A closed-circuit television system permitted observation of one subject at a time.

Procedure

Phase I: Training. After preliminary magazine training and continuous reinforcement (CRF) of lever pressing, each subject was placed on a multiple schedule described by Hearst (1965, Exp. I). On this schedule, daily sessions consisting of 96 one-min periods were divided into 64 S^D periods, 16 S^Δ periods, and 16 warning periods. The order of presentation of the periods was random except that warning and S^Δ periods were always sandwiched between one or more 1-min S^D periods, and no more than three S^D periods occurred consecutively. Warning periods were not followed by shock until discrimination training was completed. During the S^D and warning periods, lever pressing was reinforced with food pellets. In the preliminary sessions, food reinforcement was scheduled so that after variable intervals averaging 20 sec (VI 20-sec) a lever press produced one pellet (Fleshler and Hoffman, 1962). After Session 11, a VI 1-min was begun but was changed to a VI 40-sec after two sessions because of poor S^D-S^Δ discrimination.

During S^Δ periods, lever pressing was never reinforced. These S^Δ periods were signalled by a compound stimulus consisting of 2.5 clicks per second at 67 db and flashing lights (three flashes per second) for Subjects 116 and 117, and for 121 and 122 by a "white" masking noise measured at 82 db.

Warning periods were signalled by the masking noise for Subjects 116 and 117, and for 121 and 122 by the clicks and flashing lights. During warning periods, reinforcement continued to be available on the same schedule as in S^D periods.

To facilitate the S^D-S^Δ discrimination, two sessions (5 and 6) were given in which S^D and S^Δ periods of 2.5 min each occurred alternately. The S^D-S^Δ discrimination was further facilitated, beginning in the tenth session, by pairing a 50-msec duration buzzer (Potter and Brumfield, Model BU) with each lever press in S^D and warning periods. The three-component procedure with a VI 40-sec reinforcement schedule was in effect for the last six training sessions (13 to 18); the rates during these served as baseline measures for the subsequent testing phase.

Phase II: Testing. The initial test procedure consisted of adding a 0.35-ma (average current)/0.5-sec shock, measured at the grid with an Avomet II VOM meter. Shock was delivered to the subjects at the end of each of the 16 warning periods. The procedure was in effect for 11 sessions (19 to 29). Because the anticipated increase in S^Δ response rate did not take place, shock was then discontinued until the conditioned suppression that had developed in the warning periods was extinguished, *i.e.*, until the response rates returned to approximately the same in warning and S^D periods. After 10 sessions (30 to 39), the warning period suppression had disappeared, the response rates having returned to their S^D level.

To approximate more closely Hearst's (1965) shock (0.90 ma/0.35 sec), and presumably to produce his effect of increased S^Δ responding, the next test procedure consisted of adding a 0.70-ma/0.50-sec shock delivered to the subjects at the end of each warning period. This procedure remained in effect for 17 sessions (40 to 56). Because this procedure also failed to increase S^Δ responding, the subjects were again returned to the no-shock procedure. This time, however, the schedule of food reinforcement was changed from VI 40-sec to VI 2-min and the feedback buzzers were disconnected. Both of these changes were made to reduce the amount of information received by the subjects and thus increase the difficulty of the S^D-S^Δ discrimination. This was done with the thought that the more difficult a discrimination the more easily it would break down. Seven sessions (57 to 63) were conducted under these new conditions to establish baseline rates, after which the 0.70-ma/0.50-sec shock was reintroduced for 10 sessions (64 to 73). In a further effort to increase the difficulty of the discrimination, the intensities of both the masking noise and clicker were reduced to 33 db. Ten sessions (74 to 83) were given under these low-intensity conditioned stimuli (CS) conditions before extinction of the effects of shock in this last procedure was put into effect for five sessions (84 to 88). These last five sessions served to provide baseline measures for the low-intensity CS condition.

Results

Analysis of Response Rates

The values in Table 1 represent the effects of the various procedures on S^D and S^Δ responding. Measures are mean lever-pressing rates for the last three days of each procedure. In only three of the 32 individual percentage increase measures was responding greater than zero increase above baseline with the addition of electric shock (see Table 1). The largest increase was 20%, by 121 in the VI 2-min,

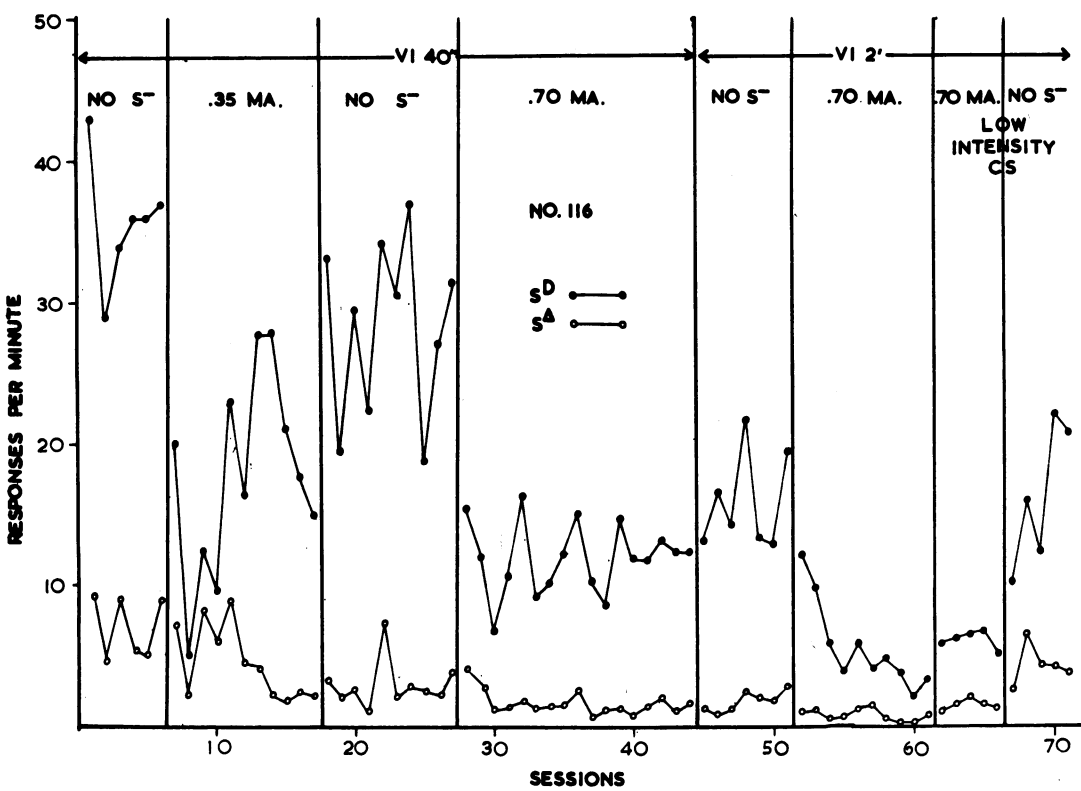

Fig. 1. "Typical" subject's response rates in S^D and S^Δ periods during Exp. I.

0.70-ma, low CS-intensity condition. In 28 cases, responding decreased (range −17% to −91%), and in one case there was less than 1% increase.

In all cases, during those phases when shock was administered, response suppression during warning periods was virtually complete.

Measures of Discrimination and Relative Suppression

It is customary for discrimination data to be represented as a ratio of S^D:S^Δ rates. Such response indices are most useful when one can assume a fairly stable S^D response rate. Without this assumption it is impossible to know if the changes in the index are due to one, the other, or both values used in the calculation. For this reason the absolute S^D and S^Δ rates, a "typical" example of which is illustrated in Fig. 1, are deemed more informative than an index. These absolute rates, along with the percentage increases presented in Table 1, are considered as the primary data in determining the effects of the various procedures.

Discussion

The results from all three procedures in this experiment failed to confirm the main finding reported by Hearst (1965), *i.e.*, an increased S^Δ rate by a stimulus-shock pairing in S^D. On the other hand, the procedures used in this

Table 1

S^D and S^Δ responses per minute and percentage increases from no-shock baselines (means for the last 3 days of each procedure).

	Condition	*S^Δrpm*	*S^Drpm*	*% Increase S^Δ*	*% Increase S^D*
#116	VI 40″ No Shock	2.60	21.62		
	VI 40″ 0.35 Shock	2.02	17.98	−22%	−17%
	VI 40″ 0.70 Shock	1.56	12.74	−40%	−41%
	VI 2′ No Shock	2.21	15.19		
	VI 2′ 0.70 Shock	0.31	3.48	−86%	−77%
	VI 2′ No Shock Low CS	3.94	18.41		
	VI 2′ 0.70 Shock Low CS	1.54	6.14	−61%	−67%
#117	VI 40″ No Shock	6.64	22.30		
	VI 40″ 0.35 Shock	2.75	25.03	−59%	+12%
	VI 40″ 0.70 Shock	6.65	17.13	±0%	−23%
	VI 2′ No Shock	3.82	14.57		
	VI 2′ 0.70 Shock	2.02	7.48	−47%	−49%
	VI 2′ No Shock Low CS	2.77	8.62		
	VI 2′ 0.70 Shock Low CS	1.04	0.90	−62%	−90%
#121	VI 40″ No Shock	14.69	36.76		
	VI 40″ 0.35 Shock	3.56	20.13	−76%	−45%
	VI 40″ 0.70 Shock	5.96	26.56	−60%	−28%
	VI 2′ No Shock	2.31	16.66		
	VI 2′ 0.70 Shock	2.50	8.45	+8%	−49%
	VI 2′ No Shock Low CS	3.54	11.55		
	VI 2′ 0.70 Shock Low CS	4.27	5.56	+20%	−52%
#122	VI 40″ No Shock	1.94	8.18		
	VI 40″ 0.35 Shock	0.17	5.16	−91%	−37%
	VI 40″ 0.70 Shock	0.47	2.00	−76%	−76%
	VI 2′ No Shock	0.29	5.68		
	VI 2′ 0.70 Shock	0.15	0.64	−48%	−89%
	VI 2′ No Shock Low CS	2.08	5.59		
	VI 2′ 0.70 Shock Low CS	0.63	0.80	−70%	−86%
Group Means	VI 40″ No Shock	6.47	22.22		
	VI 40″ 0.35 Shock	2.13	17.08	−62%	−28%
	VI 40″ 0.70 Shock	3.66	14.61	−44%	−42%
	VI 2′ No Shock	2.16	13.03		
	VI 2′ 0.70 Shock	1.25	5.01	−43%	−66%
	VI 2′ No Shock Low CS	3.08	11.04		
	VI 2′ 0.70 Shock Low CS	1.87	3.35	−43%	−74%

experiment decreased both S^{Δ} and S^{D} response rates. This result is consistent with the general finding of the conditioned suppression procedure, and aversive procedures as a whole.

The present procedure differed from Hearst's in several ways and might account for the opposite results. Hearst (1967) used a Foringer generator and scrambler to produce a 0.90-ma/0.35-sec shock. Hoffman and Fleshler (1962) scramblers with Applegate generators were used in the present experiment to produce first a 0.35-ma/0.50-sec shock and later a 0.70-ma/0.50-sec shock. Although there is some reason for believing that the 0.90-ma/0.35-sec shock might be roughly equivalent to the 0.70-ma/0.50-sec shock (Church, Raymond, and Beauchamp, 1967), there is no direct evidence available to support this contention.

Hearst used 0.1 ml diluted, sweetened milk on a VI 1-min schedule as a reinforcer. The present study employed 45-mg food pellets on VI 40-sec and VI 2-min schedules. Hearst's animals were maintained at 75% of their free-feeding weights compared to 80% used here. The S^{D} response rates of Hearst's animals on VI 1-min and those in the present study on VI 40-sec compare favorably. It is therefore doubtful that a difference in the reinforcement value of the baseline schedules could account for the discrepant results.

Wistar strain rats were employed in the present study, while Hearst used rats from the Osborne-Mendel strain. Differences between these strains, especially in their reactivity to electric shock, cannot be ruled out as a potential factor leading to the different results obtained by Hearst and in this study.

EXPERIMENT II

Despite the apparent similarity between the procedures of Exp. I and those of Hearst, the results are widely divergent. In pursuing the idea that behaviors which break down are probably weak to begin with (Ferster, 1965), it seemed possible that the subjects in Exp. I had come to be trained too well. If this were true (and it seemed tenable in the light of the various remedial procedures used in the training phase), then subjects with less training might be expected to break down easier and thus yield results consistent with Hearst's. Experiment II tested this idea.

Method

Subjects

Six experimentally naive, male, albino rats of the Wistar strain, obtained from the same supplier as in the previous experiment, were maintained in the same manner. However, this group of animals was maintained for approximately 80 days on the deprivation rhythm before the start of the experiment. They were therefore 180 days old at that time.

Apparatus

The apparatus from Exp. I was employed.

Procedure

Phase I: Training. Within two 1.5-hr sessions (1 to 2) all subjects were trained to lever-press first on a CRF schedule and then, gradually, to VI 40-sec. Each subject experienced at least 30 min of the VI 40-sec schedule which was used throughout the experiment in S^{D} and warning periods. Pre-shock discrimination training lasted only three sessions (3 to 5) during which the subjects were exposed to the three-component schedule used in Exp. I. No shock was delivered in this phase to any of the subjects. All subjects were exposed to one set of stimuli used in Exp. I, namely, an 82-db masking noise for S^{Δ} and a 67-db clicker and flashing lights for the warning stimulus.

Phase II: Testing. During the next seven sessions (6 to 12) a 0.70-ma/0.50-sec shock occurred at the end of each of the 16 warning stimulus periods for Subjects 124, 125, and 126 (three-day training group). Subjects 123, 127, and 128 continued on the procedure without shock for this period. Subjects were randomly divided into the two groups. After these seven sessions, the shock was withdrawn from the procedure for the first three rats, and for seven additional sessions (13 to 19) added to the procedure for the second three subjects (10-day training group).

Results and Discussion

Figure 2 presents the individual subjects' response rates in S^{D} and S^{Δ} during the various procedures. The main effect of the shock seems to have been rather great, overall suppression of responding. While the discrimination may not have been well established after only three or 10 days of training; lever-pressing behavior was likewise poorly established. Shock disrupted both the three- and 10-day training groups in a suppressive manner not unlike that reported in Exp. I. With the exception of Subject 127, which showed a 100% increase in S^{Δ} rate, which appears to be primarily a result of extremely low and therefore unreliable rates (0.23 and 0.46 rpm), all other subjects decreased both their S^{D} and S^{Δ} rates in the shock condition.

Except for 128, which showed no differential suppression, all other subjects had a greater percentage of baseline suppression in the presence of S^{D} (−76% group mean) than S^{Δ} (−36% group mean). This would indicate that the suppressive qualities of this procedure were not equally generalized from the warning period stimulus to S^{D} and S^{Δ}. In this regard it is interesting to note that no S^{Δ} period either followed or was followed by a warning stimulus period, whereas S^{D} periods always did. S^{Δ} periods may thus have come to signal a "safe from shock" period as well as non-reinforcement.

EXPERIMENT III

The preceding experiments were conducted on the assumption that the aversive properties of the electric shock used as the unconditioned stimulus were comparable to that used by Hearst. However, comparative examination of the effects questions this assumption. For this reason a third experiment was conducted using a lower shock intensity.

Method

Subjects

Two subjects from each of the preceding experiments were selected, namely, 121, 122, 125, and 126.

Apparatus

The apparatus was the same as that used in the previous experiments.

Procedure

Phase I: Training. Each subject received three days of training on the VI 40-sec multiple schedule described earlier. In an effort to simplify the procedure, the warning signal was eliminated. (Hearst, 1965, had found that the warning signal was not crucial to the production of increased S^{Δ} responding with shock.)

Phase II: Testing. A 0.17-ma/0.50-sec shock was added to the procedure for five sessions. Shocks occurred exactly as in Exp. I and II but without warning.

Results

Figure 3, which illustrates the S^{D} and S^{Δ} response rates, shows that two rats, 121 and 125, greatly increased their S^{D} rate of responding in the shock condition (+40% and +97% respectively). The other two subjects showed a less marked change from their no-shock baseline rates in S^{D} (+13% and −7%). Rats 122 and 126 showed a substantial increase in their S^{Δ} rates in the shock condition (+127% and +86% respectively). Only 126, however, demonstrated the effect Hearst described, namely, increased S^{Δ} responding independent of a disruption of S^{D} responding, (S^{D} −7%; S^{Δ} +86%).

Discussion

Experiment III illustrated facilitative effects of shock, although they were rather less systematic than those illustrated by Hearst. This may be due to any number of variables, but one of the more likely is that such a low current shock as 0.17 ma is approaching the physiological threshold. What is clear, however, is that from all the present evidence, Hearst's effect of breakdown of discrimination is rather elusive.

Three levels of shock, 0.17, 0.35, and 0.70 ma were investigated. At the two higher values there was no indication of an increased S^{Δ} rate; on the contrary, a decreased rate was clearly evident. The suppressive effects of shock are well documented. Facilitative effects of shock, in addition to being less frequently reported, always seem to be an inverted "U" function of the amount of shock.

Ducharme and Belanger (1961), for example, studied the effect of shock on lever-pressing rate. They shocked rats for 5 sec at 0.00, 0.08, 0.16, 0.24, 0.32, 0.40, and 0.60 ma immediately before placing them in the experimental box. They found that the response rate during the subsequent 6-min lever-pressing session increased with shock intensity up to 0.16 ma and then markedly decreased at higher values.

Strongman (1967) investigated the effect of shock administered to rats before placing them

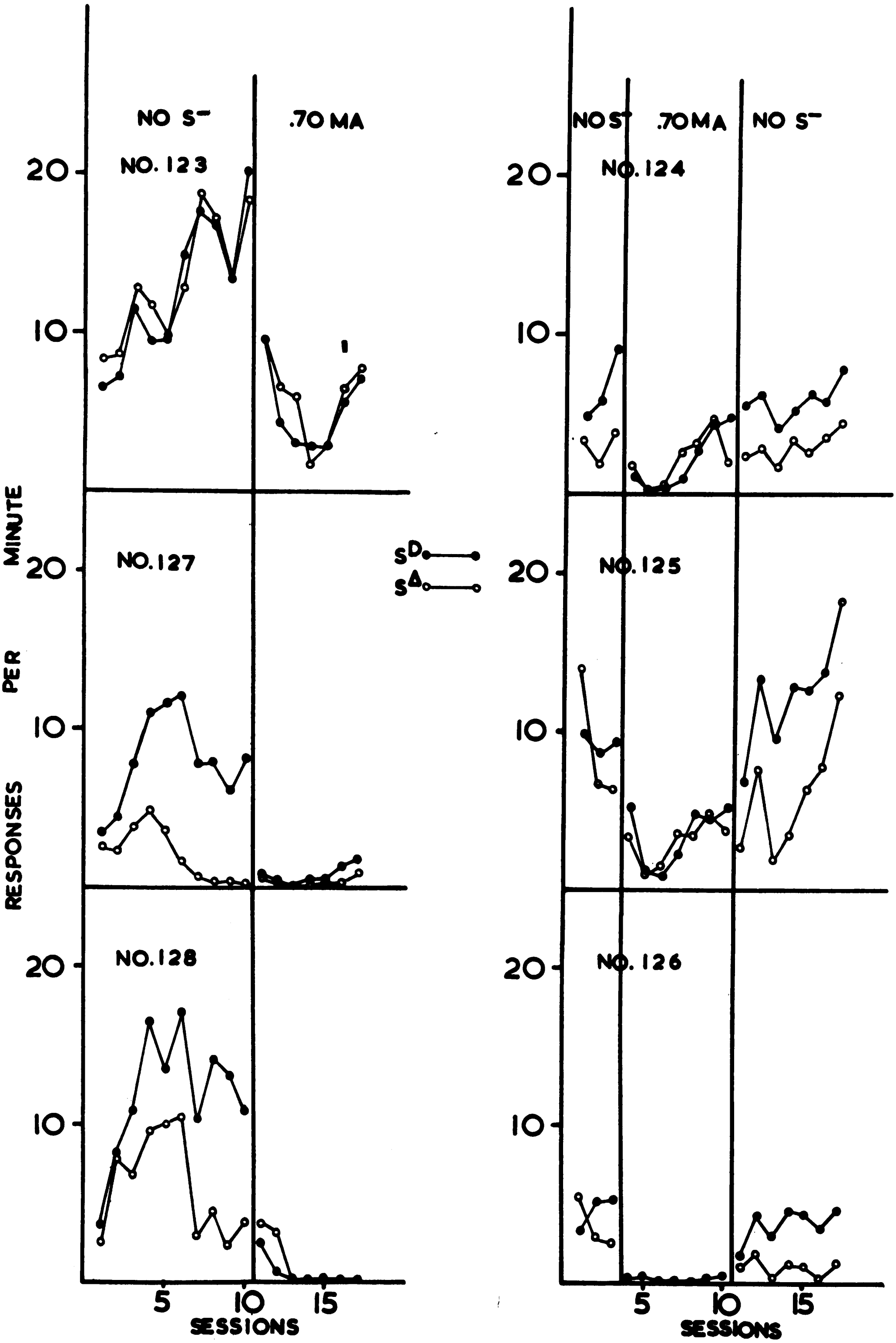

Fig. 2. Response rates in S^D and S^Δ in Exp. II.

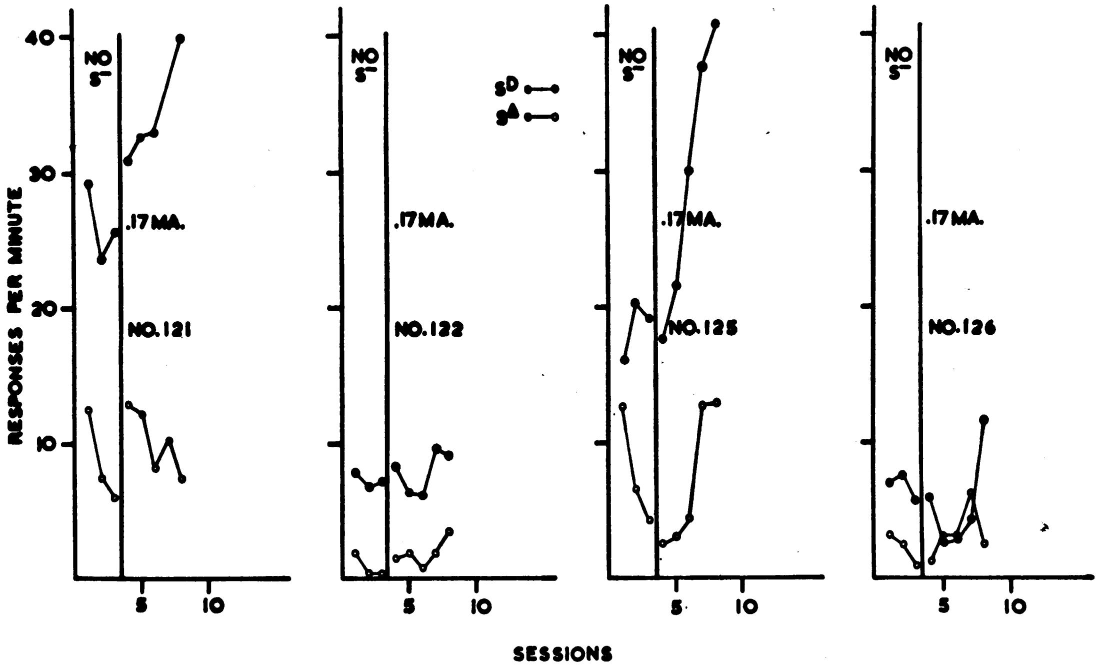

Fig. 3. Response rates in S^D and S^{Δ} in Exp. III.

in an S^D-S^{Δ} discrimination procedure. He delivered 2.6 ma for either 3, 30, or 300 sec and found that on the first day of shock the 3-sec group increased their S^{Δ} rate by 49%. However, on the second day they showed a 27% decrease compared to no-shock controls. The S^D rate in this 3-sec condition, and both the S^D and S^{Δ} rates in the 30- and 300-sec conditions, were greatly suppressed by shock on both the first and second days.

Hearst's facilitation effect was shown to be maintainable for a great number of sessions. It was not a "first day" effect as was Strongman's. Furthermore, he used a shock level in the range frequency employed for conditioned suppression (Annau and Kamin, 1961). It is certainly not clear what accounts for the discrepancy between the present results and Hearst's, but it does seem that it is not a simple case of different shock intensities. While Hearst demonstrated a facilitative effect of the conditioned suppression procedure on S^{Δ} responding, the present study demonstrated that an alternative effect is the general suppression of response rates in S^D and S^{Δ} as well as in the warning periods. Studies which have investigated the effect of either a conditioned conflict paradigm on discrimination, such as Pavlov (1927), or the effects of electric shock on consummatory behavior, nearly always reported suppression. In the light of such studies it seems reasonable to expect suppression when using the present procedure.

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